The amendments to claims 20, 21 and 33-37 do not introduce new matter. Support for the amendments to claims 20, 21 and 37 can be found, for example, in claim 23 and 25 as originally filed. Support for new claims 43-45 can be found in the specification at page 6, line 19, as originally filed. Claims 33-36 are amended solely to clarify the language of the claims. Thus, Applicants submit that this Amendment does not introduce new matter.

I. Rejection under §112, Second Paragraph

Claims 33-36 are rejected under 35 U.S.C. §112, second paragraph, as allegedly being indefinite. The Office Action rejects claims 33-36 because a rate is allegedly only defined by a percent. Applicants respectfully traverse this rejection.

Contrary to the Office Action's suggestion that the claim is drawn to a rate, which implies a change in a parameter per unit time, the lowering of conversion efficiency due to photo-degradation refers to a value determined based on the difference in conversion efficiency in a solar cell before and after exposure to a solar simulator, for example a halogen lamp, for a given period of time. Thus, it is not the change in the conversion efficiency over time that is claimed, but instead the loss in conversion efficiency that is claimed. The language of claims 33-36 is amended to more clearly reflect this meaning of the phrase.

In view of the above remarks and the amendments to claims 33-36, this rejection should be withdrawn. Reconsideration and withdrawal of the rejection are respectfully requested.

II. Rejection under §102

Claim 20 is rejected under 35 U.S.C. §102(b) as allegedly anticipated by Izunome et al. (US 5,700,320). Applicants respectfully traverse this rejection.

As amended, claim 20 indicates that the diameter of the single crystal is 4 inches or more and that the single crystal is used for a solar cell. Based on these features, the claimed invention is distinct from the single crystal disclosed by Izunome because the present invention can prevent photo-degradation due to oxygen and boron. Such photodegradation is a common problem in boron doped silicon single crystal. By doping the silicon single crystal

with Ga according to the present invention, photo-degradation does not occur even in single crystals that have high oxygen concentrations. The claimed invention thus provides a silicon single crystal for producing a solar cell that has a very high conversion efficiency. Conventionally, a single crystal for high efficiency energy conversion used in a solar cell is produced according to the FZ method or MCZ method in order to minimize the oxygen concentration, but such crystals are of significantly smaller diameter.

In contrast, the claimed invention provides for a silicon single crystal having a large diameter that may be produced using the CZ method. Although Izunome discloses a silicon single crystal that has a Ga concentration within the range of the claimed invention, the cited reference fails to disclose the use of the single crystal for a solar cell. In addition, the silicon single crystal disclosed by Izunome only has a diameter of 3 inches. Thus, the single silicon crystal of Izunome does not correspond to and cannot exhibit the same effects as the claimed invention when used for a solar cell.

Thus, Applicants submit that the cited reference does not anticipate the claimed invention. Reconsideration and withdrawal of the rejection are respectfully requested.

Applicants submit that new claim 43, which depends from claim 20 and thus includes all the limitations of claim 20, is anticipated for at least the reasons discussed above.

III. Rejection under §103

Claims 21-32 and 37-42 are rejected under 35 U.S.C. §103(a) as allegedly unpatentable over Izunome and further in view of Wolf et al. (Silicon Processing for the VLSI Era, Vol. 1: Processing Technology, Lattice Press, Sunset Beach, CA, USA pp. 1-35, 1986), Ravi et al. (US 4,152,536) and Minahan et al. (Conf. Rec. IEEE Photovoltaic Spec Conf. (1982), 16th 310-315). Applicants respectfully traverse this rejection.

The Office Action cites and applies Izunome as discussed in the rejection above. However, the Office Action admits that the reference fails to teach or suggest further uses,

properties and methods of forming doped silicon single crystals. To cure the deficiencies in the teachings of Izunome, the Office Action cites Wolf, Ravi and Minahan.

The Office Action cites Wolf for teaching a silicon single crystal having a diameter of 8 inches or more. Ravi is cited for teaching solar cells having a range of resistivity that encompasses the resistivity range of the claimed invention. The Office Action cites Minahan for teaching a Ga-doped CZ silicon single crystal that is used for solar cells.

However, as amended, claim 21 specifies that the diameter of the single silicon crystal is 4 inches or more, and that the single silicon crystal is used for a solar cell. Claim 37 is similarly amended to indicate that the silicon single crystal ingot has a diameter of 4 inches or more and that the single crystal is used in a solar cell. Applicants respectfully submit that the claimed invention would not have been obvious over the combined teachings of the cited references.

As discussed in the previous rejection, Izunome fails to disclose, and likewise fails to teach or suggest, a Ga-doped CZ silicon single crystal having a diameter of 4 inches or more that is used for a solar cell. In addition, Izunome teaches that since impurity non-uniformity is likely to occur at the interface of crystal growth in a silicon melt doped solely with Ga, it is preferable to dope a silicon single crystal with Ga and B (see Izunome, claim 3, and col. 2, lines 31-37). Thus, the reference teaches away from doping the silicon solely with Ga. Based on the teachings of Izunome, one of ordinary skill in the art would not have been motivated to dope the silicon single crystal only with Ga, as claimed.

With respect to the teachings of Wolf, the cited reference only describes the diameter of a general silicon single crystal doped with B or P, but fails to suggest a silicon single crystal doped with Ga as in the present invention. In addition, Wolf fails to teach or suggest using the silicon single crystal to produce a solar cell. In fact, the reference only teaches general properties of and a processing method for a silicon single crystal. Applicants respectfully submit that in view of the teachings of Wolf, one of ordinary skill in the art

would not have been motivated to modify the teachings of Izunome to produce a silicon single crystal having the claimed dimensions and doped only with Ga. To the contrary, the combined teachings of Izunome and Wolf would instead lead one of ordinary skill in the art to dope the silicon single crystal with Ga in combination with B or P. However, this would be contrary to the claimed invention.

Although Ravi describes a silicon single crystal that is used for solar cells having a resistivity that encompasses the range of resistivity of the claimed invention, Ravi does not teach or suggest that solar cells are produced from a Ga-doped CZ silicon single crystal. Instead, the resistvity of silicon single crystal taught by Ravi relates to a B-doped crystal. Furthermore, Ravi fails to teach or suggest anything with respect to the diameter of the silicon single crystal. In essence, the reference only discusses solar cells produced from a conventional B-doped CZ silicon single crystal. Again, the combined teachings of Izunome and Wolf, in conjunction with Ravi, would not have led one of ordinary skill in the art to make the necessary modifications to dope the silicon single crystal only with Ga having the claimed dimensions and resistivity.

As for Minahan, the silicon single crystal described by the cited reference only has a diameter of 2 inches (see Minahan, page 331, left col., lines 3-4). Moreover, the Ga-doped silicon single crystals described by Minahan have resistivities that are beyond the range of the claimed invention, (see Minahan, e.g., page 310, right col., lines 32-35, and page 313, table 2). Crystals having the resistivity as taught by Minahan would have reduced conversion efficiency. Although Minahan arguably suggests a Ga-doped CZ or FZ silicon single crystal, the resistivity of such a crystal is 10 Ω·cm (see Minahan, e.g., page 313, tables 3a-3c). The reference does not teach or suggest a Ga-doped CZ silicon single crystal having a resistivity of from 5 Ω·cm to 0.1 Ω·cm that would also have properties desirable in a solar cell. In short, Minahan only describes a Ga-doped silicon single crystal used for a solar cell, but does not teach or suggest the claimed diameter and resistivity of the claimed invention. Combining

the teachings of Minahan with Izunome, Wolf and Ravi would not have yielded the claimed invention as the other references do not teach or suggest doping only with Ga. In fact, the Izunome teaches away from making a complete substitution of Ga for B in order to avoid impurity non-uniformity at the interface of crystal growth.

Applicants also submit that the claimed invention possesses properties that would not have been expected based on the teachings of the cited references. None of the cited references teach or suggest that photo-degradation due to boron and oxygen concentration on a solar cell can be prevented by substituting Ga for B. The references also do not teach or suggest and that by making this substitution, a single crystal having a diameter greater than 4 inches having excellent conversion efficiency in a solar cell can be obtained, despite the likelihood of higher oxygen concentration within the single crystal. Furthermore, the cited references fail to teach or suggest that the resulting resistivity of the single crystal must be kept within a certain range in order to achieve the higher conversion efficiency.

In view of the teachings of the cited references, one of ordinary skill in the art would not have been apprised of the effects described above because none of the cited references teach or suggest anything regarding the properties described in conjunction with the claimed invention.

For at least these reasons, claims 21-32 and 37-42 would not have been obvious over the cited references. Reconsideration and withdrawal of the rejection are respectfully requested.

Applicants submit that new claims 44 and 45, which respectively depend from claims 21 and 37 and thus includes all the limitations of claims 21 and 37, would not have been obvious over the cited references for at least the reasons discussed above.

IV. Conclusion

In view of the foregoing amendments and remarks, Applicants submit that this application is in condition for allowance. Favorable reconsideration and prompt allowance of claims 20-22, 24 and 27-45 are earnestly solicited.

Should the Examiner believe that anything further would be desirable in order to place this application in better condition for allowance, the Examiner is invited to contact Applicants' undersigned representative at the telephone number set forth below.

Respectfully submitted,

William P. Berridge
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WPB/SXT:amw

Attachment:
Appendix

Date: October 30, 2002

OLIFF & BERRIDGE, PLC
P.O. Box 19928
Alexandria, Virginia 22320
Telephone: (703) 836-6400

DEPOSIT ACCOUNT USE AUTHORIZATION
Please grant any extension necessary for entry;
Charge any fee due to our Deposit Account No. 15-0461

APPENDIX

Changes to Claims:

Claims 23, 25 and 26 are canceled.

The following is a marked-up version of the amended claims:

20. (Amended) A silicon single crystal produced according to Czochralski method to which Ga (gallium) is added as a dopant wherein a resistivity is 5 Ω·cm to 0.1 Ω·cm wherein a diameter of the single crystal is 4 inches or more, and the single crystal is used for a solar cell.

21. (Amended) A silicon single crystal produced according to Czochralski method to which Ga is added as a dopant wherein concentration of Ga in the crystal is 5×10^{17} atoms/cm^3 to 3×10^{15} atoms/cm^3 wherein a diameter of the single crystal is 4 inches or more, and the silicon single crystal is used for a solar cell.

33. (Amended) The silicon single crystal solar cell according to Claim 27, wherein ~~a rate of lowering of a~~loss of overall conversion efficiency due to photo-degradation is 0.5 % or less.

34. (Amended) The silicon single crystal solar cell according to Claim 29, wherein ~~a rate of lowering of a~~loss of overall conversion efficiency due to photo-degradation is 0.5 % or less.

35. (Amended) The silicon single crystal solar cell according to Claim 30, wherein ~~a rate of lowering of a~~loss of overall conversion efficiency due to photo-degradation is 0.5 % or less.

36. (Amended) The silicon single crystal solar cell according to Claim 32, wherein ~~a rate of lowering of a~~loss of overall conversion efficiency due to photo-degradation is 0.5 % or less.

37. (Amended) A method for production of silicon single crystal wafer to which Ga is added according to Czochralski method wherein Ga is added in a silicon melt in a crucible, a seed crystal is brought into contact with the silicon melt and is pulled with rotating to grow a silicon single crystal ingot having a diameter of 4 inches or more used for a solar cell.